

# Improve Power Quality In Photovoltaic And Wind Energy Systems By Employing PWM And PR Controller Techniques

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## Abstract

As new technologies are adopted and renewable energy sources are gradually integrated, modern power networks are evolving into complex hybrid configurations. However, care must be taken in addressing the power quality issues brought on by this change. By examining different approaches, this study seeks to improve power quality in hybrid power systems. Maintaining consistent power quality has become more challenging due to the growing integration of renewable energy sources and the complexity of contemporary power systems. In order to enhance power quality in a hybrid power system, this study addresses the application of two cutting-edge power techniques: PR controller techniques and PWM (Pulse Width Modulation).

**Key words** PQs (Power Quality System), PVs (Photovoltaic system), Wind Energy System, PWM technique, PR controller

## 1.INTRODUCTION

The integration of photovoltaic (PV) and wind energy sources in hybrid power systems has garnered significant attention as the world moves toward a more ecologically conscious and sustainable energy framework [1,2]. To make better use of renewable energy, these systems combine the intermittent generation characteristics of wind and solar resources. However, there are issues with power quality when such diverse sources are integrated into the power grid. The reliability and efficiency of the power supply are impacted by a number of variables that make up power quality, including reactive power balance, frequency regulation, harmonics, and voltage stability. Improved energy output and a reduced dependency on conventional fossil fuels are two advantages of hybrid PVwind power systems.

However, voltage swings, frequency changes, and other undesired power quality issues may arise from these renewable sources' inherent unpredictability and intermittency [3]. To ensure the seamless and reliable integration of hybrid systems into the existing grid infrastructure, these problems need to be carefully resolved. The important topic of improving power quality in hybrid PV-wind power systems is examined in this paper [4]. It aims to compare approaches that can mitigate these issues and provide insight into the power quality issues associated with these systems. The feasibility and efficiency of hybrid PV-wind power systems can be greatly enhanced by successfully enhancing power quality, hastening the transition to greener and more sustainable energy sources.

The specific power quality issues that hybrid PV-wind power systems face will be discussed in the sections that follow. We will then explore two technologies that can be applied to mitigate these issues and improve power quality. In order to illustrate the usefulness and practical implementation of the proposed solutions, this paper will include simulations and results.

## 2. MODEL OF A HYBRID RENEWABLE ENERGY SYSTEM

One promising way to meet the demands of electrical load is with a hybrid generating system that integrates with the grid. This hybrid configuration can provide reliable power in both standalone and grid-connected modes by utilizing the advantages of both solar and wind energy systems [6]. In addition to reducing costs, the system's overall efficiency and dependability are enhanced by the grid integration. The hybrid system captures sustainable energy and distributes it to connected loads regardless of the weather. This hybrid renewable energy system's main benefits include a lower peak load, fewer conduction line losses, supply in remote locations, and increased overall dependability [7].

The hybrid power system discussed in this paper is made up of both variable renewable sources, like solar and wind, and predictable sources. Power quality may suffer as a result of voltage and current variations brought on by renewable energy's variable nature. The system incorporates the D-STATCOM to lessen these difficulties. Through the injection of reactive power, the D-STATCOM is essential to the management of variable voltage [8]. By reducing voltage sags, swells, and flickers, this action contributes to a steady and dependable voltage profile. Additionally, the D-STATCOM improves the system's power factor, which lowers overall system losses.

## 3. FUNDAMENTAL STRUCTURE OF THE SYSTEM

There is a lot of promise for meeting the world's energy needs while lowering greenhouse gas emissions by integrating renewable energy sources like wind and photovoltaic (PV) into hybrid power systems [10]. However, these systems' ability to deliver a reliable and superior power source determines how effective they are. By addressing power quality concerns, we pave the way for a stable and reliable energy future, where hybrid PV-wind power systems play a critical role in promoting environmental sustainability. The basic architecture of the hybrid system connected to the grid system is depicted in figure 1.

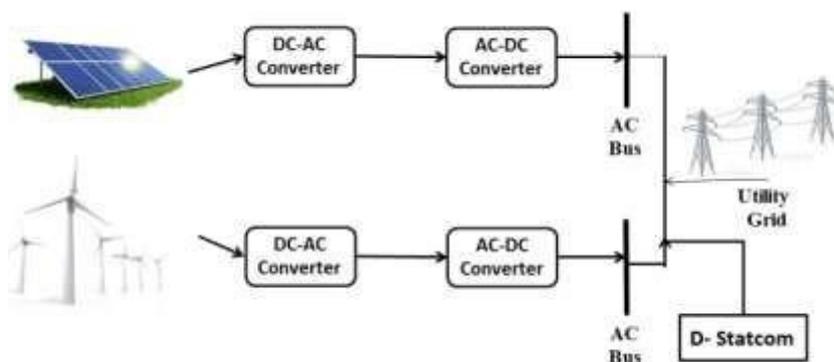


Figure 1 Basic construction of hybrid system

## 4. PWM CONTROL TECHNIQUES

Modern motor drives increasingly use switching power converters to transform and provide the required energy to the motor as a result of improvements in solid-state power devices and microprocessors. Pulse Width Modulated (PWM) signals applied to the gates of the power transistors control the energy supplied to a motor by a switching power converter [11]. PWM signals are made up of pulse trains with a variable pulse width and a fixed frequency and magnitude. There is only one fixed-magnitude pulse per PWM period. However, depending on a modulating signal, the width of these pulses changes from one pulse to the next.

When a PWM signal is applied to a power transistor's gate, the transistor's turn-on and turn-off times change from one PWM cycle to the next in response to the same modulating signal. In order for the modulating signal to be the primary determinant of the energy supplied to the motor and its load, the fundamental frequency, which is the frequency of the PWM signal, should be substantially higher than that of the modulating signal [12]. Figure 2 is representing the basic block diagram of System connected to grid.

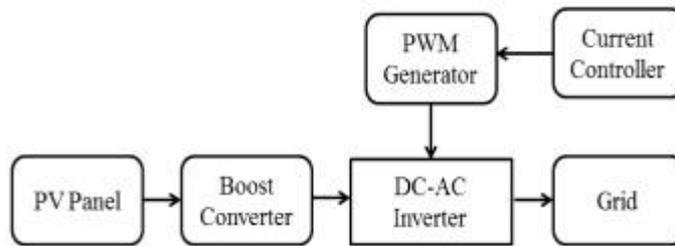


Figure 2 Basic block diagram of System to grid

5.PR CONTROLLER TECHNIQUE

The following formula represents the PR's current controller GPR(s):

$$G_{PR}(s) = K_P + K_I \frac{1}{s} \frac{2\omega_0}{2 + \omega_0^2} \dots\dots 1$$

Here,  $\omega_0$  is the resonant frequency,  $K_I$  is the integral gain term, and  $K_P$  is the proportional gain term [13, 14].

Only the PR controller's ideal resonant term provides an infinite gain at the ac frequency  $\omega_0$ , with no phase shift or gain at other frequencies [15, 16]. The dynamics of the system, such as bandwidth, phase, and gain margins, are influenced by the  $K_P$  term. The ideal PR controller, however, behaves like a network with an infinite quality factor, which makes it difficult to put into practice. First off, neither analogue nor digital systems can achieve the infinite quality factor that the PR controller's infinite gain produces.

Second, the PR controller's gain drastically drops at other frequencies, which means it isn't enough to remove the grid voltage's harmonic influence. To overcome these problems, a high-gain lowpass filter is used in (3) to create an approximate ideal (non-ideal) PR controller [17, 18].

Because of its infinite gain, the ideal PR controller shown in equation (2) could cause stability problems. As shown in (3) below, damping can be used to make the PR controller less-than-ideal in order to address these issues:

$$G_{PR}(s) = K_P + K_I \frac{2\omega_0 s}{s^2 + 2\omega_0 \zeta s + \omega_0^2} \dots\dots 2$$

Here,  $\zeta$  stands for the bandwidth around  $\omega_0$ 's ac frequency. Equation (3) indicates that the PR controller's gain at the ac frequency  $\omega_0$  is now finite, but it is still high enough to guarantee that the steady state error is kept to a minimum. Additionally, because digital systems have limited precision, this equation makes it easier to implement the controller [19, 20].

6.SYSTEM SIMULATION AND RESULT

Two separate scenarios are typically included in the simulation process:

1. Condition I: PV and wind system simulation results using the D-STATCOM with PWM technique.
2. Condition II: PV and wind system simulation results using the D-STATCOM with PR controller technique. MATLAB/Simulink has been used to carry out this setup. Within a particular subsystem, the control loop and the renewable energy system have been built. The Simulink block diagram shown in Figure 3 shows the configuration that was put into place, which accounts for an unbalanced nonlinear load with D-STATCOM for the wind and PV system using PWM technique.

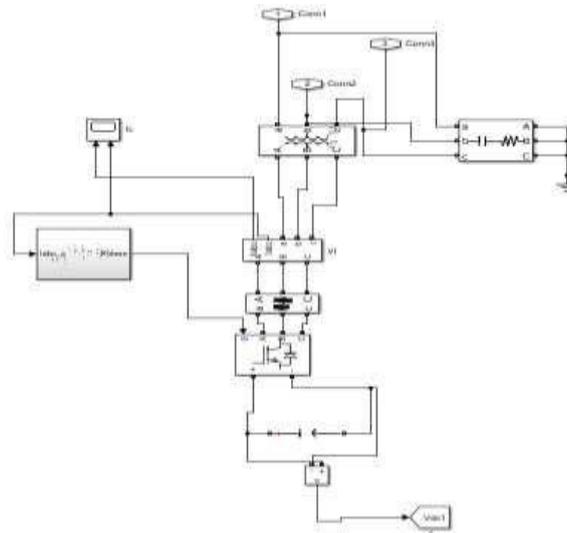


Figure 3 Simulation diagram of D-STATCOM using PWM Technique

**6.1 Condition I: PV and wind system simulation results using the D-STATCOM with PWM technique** Now shown in the figure 4 and 5, the simulation of the Wind generational and the PV system with PWM technique. In figure 6 represent the PWM control technique in simulation.

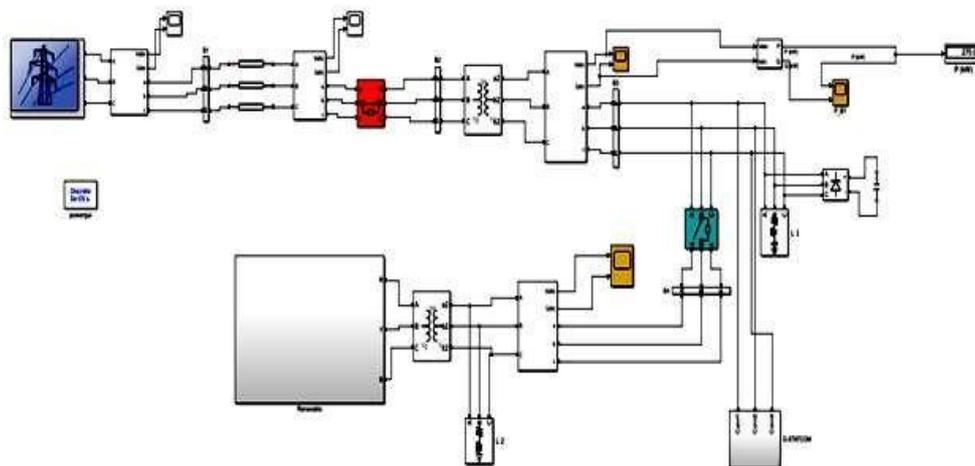


Figure 4 Simulink complete model of Wind generation using PWM technique

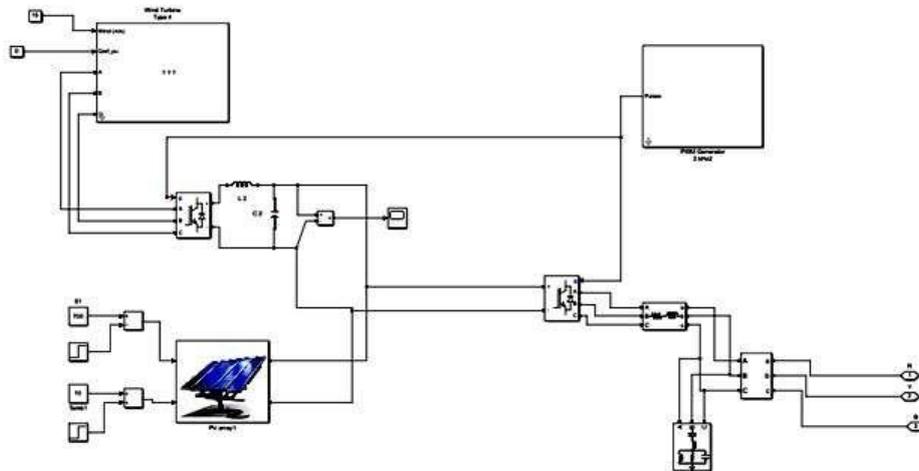


Figure 5 Simulink model of PV & Wind generation using PWM technique

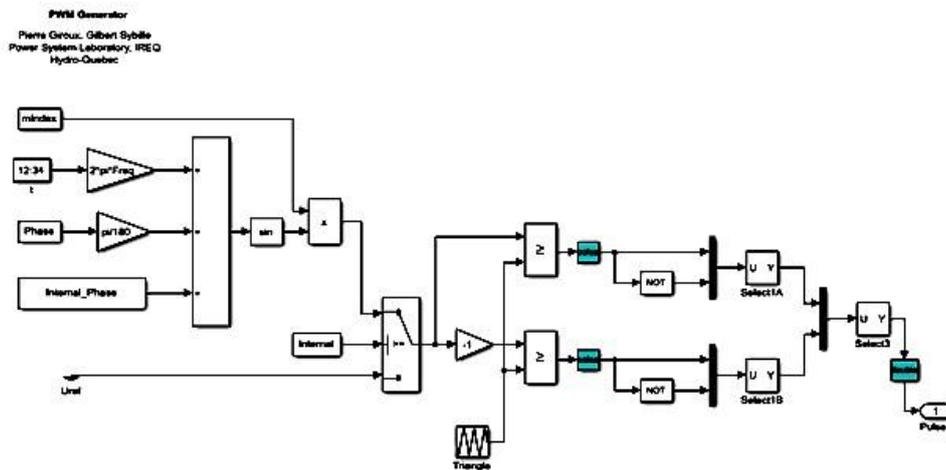


Figure 6 Simulink model of PWM control technique

### RESULT DISCUSSION:

Shown in the figure 7, output voltage and current. In figure 8 represent the active and reactive power in our system and figure 9 present the THD output of the system.

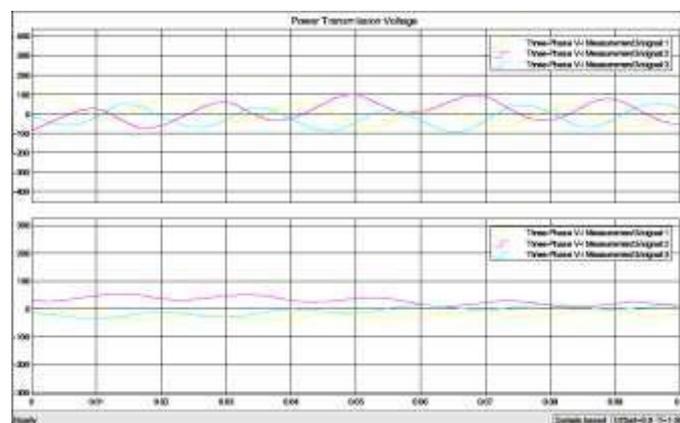


Figure 7 System Output Voltage and Current

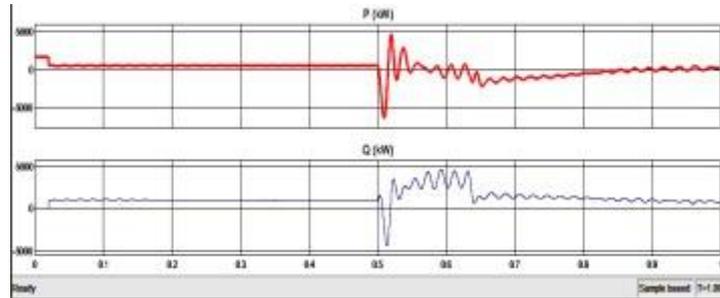


Figure 8 System Active and Reactive Powers

**THD (Total Harmonics Distortion) For PWM Technique:**

The following plot shows the THD of the source current and source voltage with DSTATCOM PV and Wind system using PWM technique the THD of the source is 7.16%.

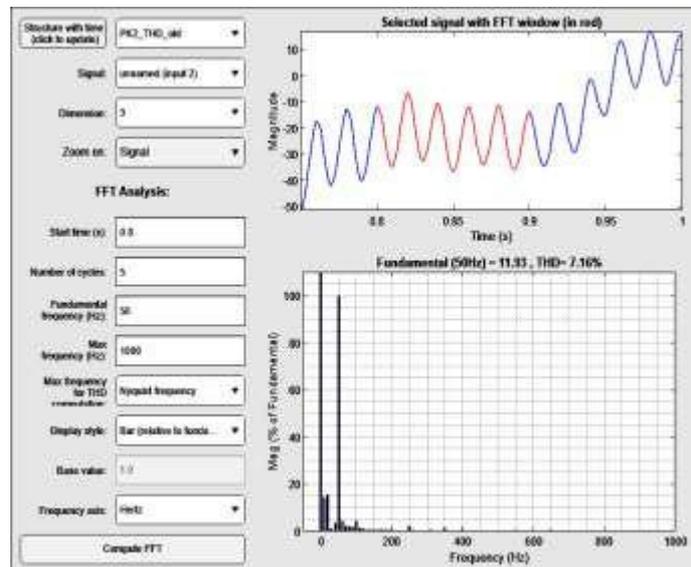


Figure 9 System THD system

**6.2 Condition II: PV and wind system simulation results using the D-STATCOM with PR controller technique**

Now shown in the figure 10 and 11, the simulation of the Wind generational and the PV system with PWM technique. In figure 12 represent the PWM control technique in simulation.

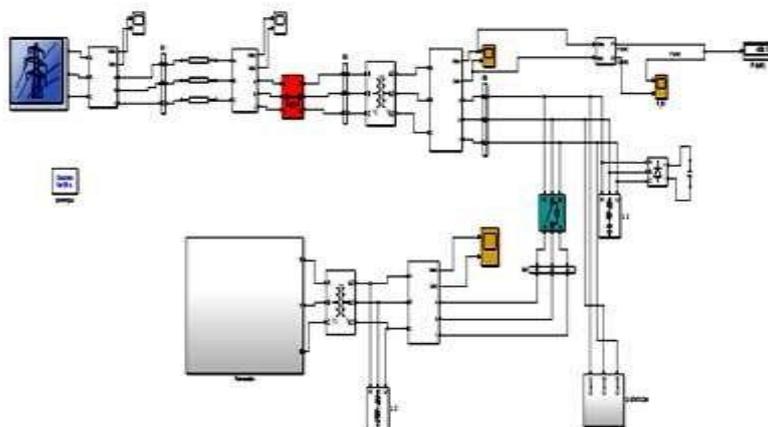


Figure 10 Simulink completed model of Wind generation using PR controller technique

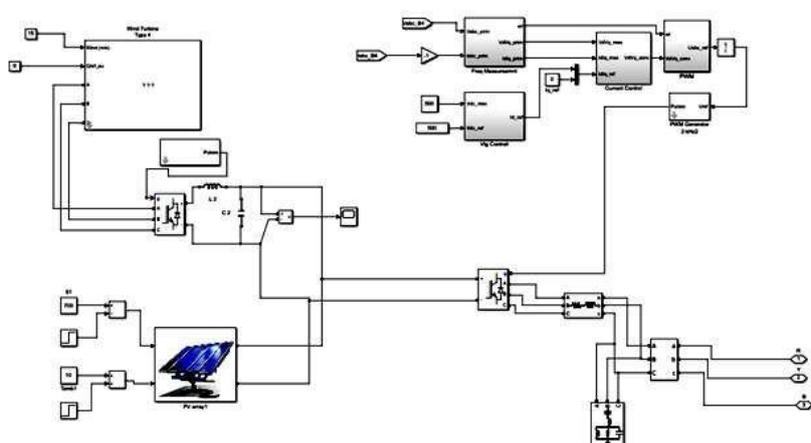


Figure 11 Simulink model of PV & Wind generation using PR controller technique

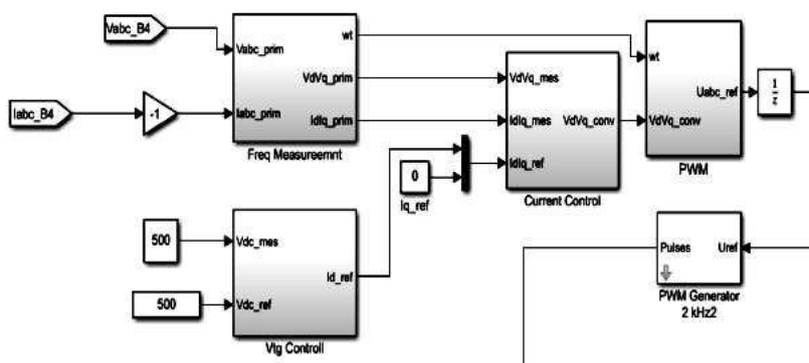


Figure 12 Simulink model of PR control technique

### RESULT DISCUSSION:

Shown in the figure 13, output voltage and current. In figure 14 represent the active and reactive power in our system and figure 15 present the THD output of the system.

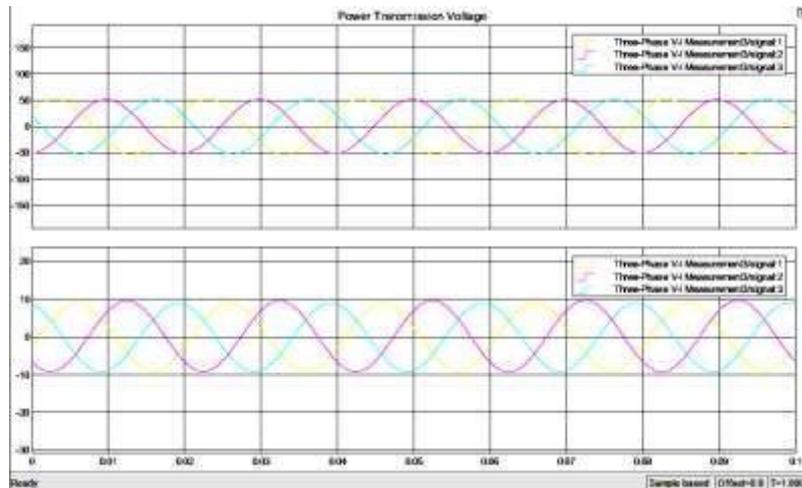


Figure 13 System Output Voltage and Current

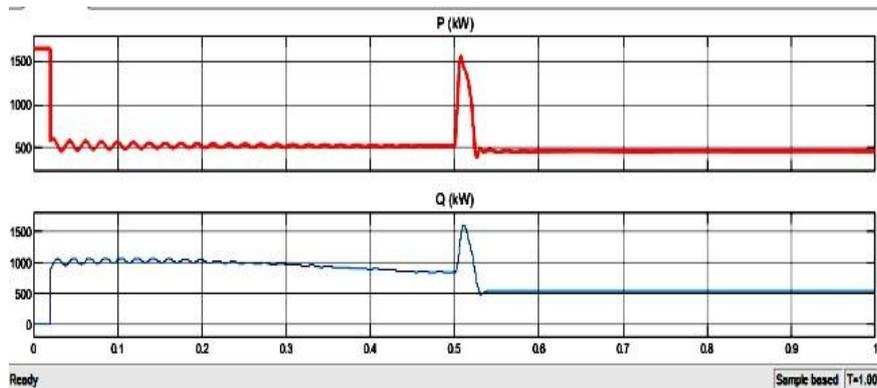


Figure 14 System Active and Reactive Powers

**THD (Total Harmonics Distortion) for PR controller Technique:**

The following plot shows the THD of the source current and source voltage with D-STATCOM PV and Wind system using PR controller technique the THD of the source is 0.54%.

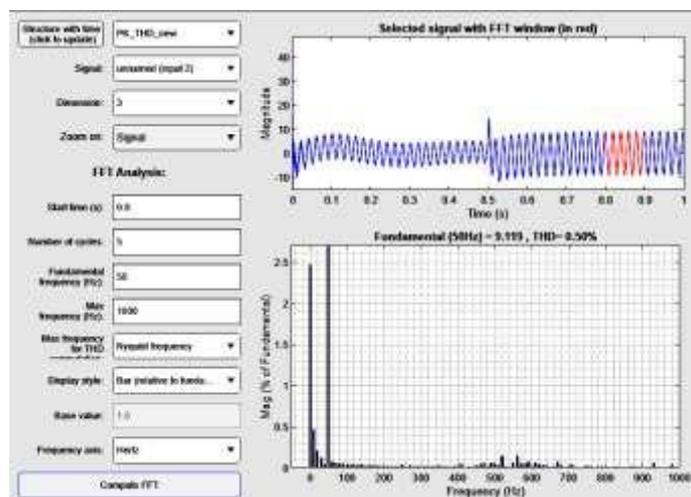


Figure 15 System THD system

## 7.CONCLUSION

The main objective of this paper was to develop and verify a controller technique for DSTATCOM that would effectively regulate voltage, compensate for reactive power, enhance power factor, and address unbalanced loads. The study primarily focused on implementing PWM and PR controller techniques to improve power quality through the utilization of DSTATCOM. Additionally, an active power filter was employed to mitigate harmonic distortion.

It is observed that the THD of the current supplied at the wind system and PV system with connecting DSTATCOM using PWM technique is 7.16% which is very high and even not within the limit set by IEEE. According to the standards set by IEEE for power quality issues, THD must be less than 5%. By using PR controller technique, the THD in current supplied by the hybrid wind-PV system lowers to 0.54% which is a better result compared to the other. This means that the power quality has improved using PR Controller Technique.

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